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Mark J. McCabe
SKEMA Business School

Christopher M. Snyder
Dartmouth College, Christopher.M.Snyder@dartmouth.edu

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Academic Journal Prices in a Digital Age: A Two-Sided-Market Model

Mark McCabe
Georgia Institute of Technology

Christopher M. Snyder
Dartmouth College

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Abstract: Digital-age technologies promise to revolutionize the market for academic journals as they have other forms of media. We model journals as intermediaries linking authors with readers in a two-sided market. We use the model to study the division of fees between authors and readers under market structures ranging from monopoly to free entry. The results help explain why print journals traditionally obtained most of their revenue from subscription fees. The results raise the possibility that digitization may lead to a proliferation of online journals targeting various author types. The paper contributes to the literature on two-sided markets in its analysis of free-entry equilibrium and modeling of product-quality certification.

Keywords: Open access, scholarly journal, two-sided market, competition

JEL Codes: L14, L82, D40, L31

Contact Information: Mark McCabe, School of Economics, Georgia Institute of Technology, 781 Marietta Street, N.W., Atlanta, GA 30318, email mark.mccabe@econ.gatech.edu, tel. (404) 385-0512. Christopher M. Snyder, Department of Economics, Dartmouth College, 301 Rockefeller Hall, Hanover, NH 03755, email Christopher.M.Snyder@dartmouth.edu, tel. (603) 646-0642.

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1. Introduction

The market for academic journals is in a state of flux. Library subscription fees, the chief source of revenue for commercial academic publishers, have been rising in real terms over the past several decades (McCabe 2002, Dewatripont *et al.* 2006) to the point that commercial journals' prices are an order of magnitude higher than non-profits' (Bergstrom 2001, Dewatripont *et al.* 2006). At the same time, new technologies, including digitization and the Internet, hold out the possibility of revolutionizing academic journals along with all other forms of media. These new technologies will certainly alter the cost structure of academic journals, with ramifications for pricing, market structure, and even the very essence of what academic journals are.

The market for academic journals is important to study. Prices have risen to the point at which libraries are beginning to cancel significant titles (Weiss 2003), suggesting the possibility for significant deadweight loss. The deadweight loss may be felt by readers who lose access to significant scholarship and authors whose articles' impact and citations are diminished. Since journals are a channel for dissemination of knowledge in the economy, frictions in this channel may have much broader implications for the economy as a whole.¹

In this paper, we develop a theoretical framework for understanding the impact of the digital revolution on journal prices, quality, and market structure. The key feature of the journals market captured in our framework is its "two-sided" nature. Subscribers on one side of the market benefit from the scholarship of authors on the other side. Conversely, authors benefit from having a large number of readers. Journals serve as intermediaries between the two sides.

Drawing on the growing industrial-organization literature on two-sided markets, we develop a model tailored to the case of academic journals.² The model captures three unique features of the journal market. First, while readers can subscribe to many journals simultaneously, authors can only publish an article in one. In the parlance of the two-sided-markets literature, authors "singlehome" and readers "multihome." Second, journals bundle a number of articles together in a

¹Another reason for analyzing the journals market for an academic audience is that it is one of the few markets that academics participate in as producers and consumers and exercise some control over as journal founders and editors.

²The literature on two-sided markets includes Ambrus and Argenziano (2005); Armstrong (2006); Baye and Morgan (2001); Caillaud and Jullien (2003); Evans (2003); Hagiu (2006a, 2006b); Hermalin and Katz (2004); Jeon, Laffont, and Tirole (2004); Laffont *et al.* (2001); Rochet and Tirole (2002, 2003, 2006); Schmalensee (2002); and Wright (2004a, 2004b).

single issue. Our model endogenizes bundling (we will see this is a way to economize on the fixed cost of serving a reader). Third, articles may vary in quality. Although for simplicity we take articles to be of homogeneous quality in the basic variant of the model, we allow for heterogeneous article quality in an extension in Section 5.4. In that extension, readers prefer high quality articles and authors wish to be certified by a high-quality journal as indexed by the average quality of articles it publishes.

We use the model to understand how the traditional structure of academic journal prices, with zero or low author fees on one side and high subscription fees on the other, might have arisen. We analyze how a change in the structure of journal costs due to digital technologies may change the structure of journal prices. We study the efficiency and competitive viability of a new model of journal pricing, open access, advocated by a growing number of scholars and librarians. The open-access model turns the traditional pricing model on its head, making articles freely available to readers over the Internet and deriving revenues instead from high author fees. We explore how the market structure of journals may evolve in response to entry and competition. Will one journal emerge that serves as a centralized intermediary between all authors and readers, or will niche journals emerge serving different segments of the market? How does the answer depend on costs and author- and reader-demand conditions?

The analysis begins in Section 3 with the monopoly case. The analysis shows that a monopoly journal has no inherent reason to favor either authors or readers in its pricing. The monopolist is interested in extracting revenue from all possible sources. One side of the market would obtain relatively favorable prices only if there is a great deal of asymmetry between author and reader benefits or costs. For example, the monopolist may charge low or zero fees (open access) to readers if benefits on the author side of the market are much greater than on the reader side. Conversely, the monopolist may charge low or zero submission fees if the benefits on the reader side dominate those on the author side.

As shown in our analysis of free-entry equilibrium in Section 4, competition changes matters. The fact that authors “singlehome” while readers “multihome” leads competition to be relatively tougher for authors than for readers. Readers cannot freely substitute across journals because each has an effective monopoly over the articles published there. If the journal’s fixed cost of serving an additional reader (denoted c^R , distinct from the transaction cost of delivering a single article to a single reader, denoted c) is low enough, then in equilibrium there is a proliferation of journals that are each targeted to authors of particular types. Different journals

may offer different points on the submission-fee/readership-size frontier. On the other hand, if c^R is sufficiently high, a few—or in the extreme one—journal may publish all articles, since having few journals economizes on the duplication of fixed reader costs. The pressure of potential entrants keeps the submission fee low, in many instances reducing it to zero. The model thus provides an explanation of why author fees over the previous several decades—essentially a print-journal environment in which c^R is high—have generally been low, and thus a much less important source of revenue than subscription fees. To the extent that new digital technologies can be expected to reduce c^R , one can expect an expansion of entering journals into various price-point/quality niches.

In related literature, the most comprehensive treatment of new policy issues facing the academic-journals market in the digital age is Dewatripoint (2006), which also contains a detailed empirical analysis of pricing trends. Besides our own previous work,³ the existing theoretical literature on academic journals, including McCabe (2004) and Jeon and Menicucci (2006), takes as given that the only source of revenue is library subscription fees, and thus cannot be used to analyze the division of fees across authors and readers that the present paper’s two-sided-market model can.

The present paper contributes to the industrial-organization literature on two-sided markets by being the first analysis of free-entry equilibrium among homogeneous platforms. Most of the literature on competition in two-sided markets considers competition between at most two platforms, and the two platforms are generally assumed to be differentiated (e.g., Armstrong 2006, Rochet and Tirole 2003, Rochet and Tirole 2006). Exceptions that are closer to our work include Caillaud and Jullien (2003), Ambrus and Argenziano (2005), and Hagiu (2006b). Caillaud and Jullien (2003) analyze Bertrand competition among two homogeneous platforms, but the imperfect matchmaking technology assumed in their model effectively leads to imperfect competition between them. Ambrus and Argenziano (2005) analyze homogeneous duopoly platforms. The partition equilibria we derive

³McCabe and Snyder (2006) is an ancillary paper that analyzes the alternative modeling assumption of lump-sum prices rather than per-reader or per-article prices assumed here. Equilibria are much harder to characterize in that ancillary paper, and many results have to be stated as possibility results, proved with numerical examples. Another difference is that McCabe and Snyder (2006) does not analyze free-entry equilibrium. McCabe and Snyder (2005) sketches the analysis of a model in which talented editors weed out bad papers that are costly for subscribers to read but provide no benefits. The analysis is less general than in the present paper, only analyzing the case of monopoly under the assumption that authors have homogeneous valuations, essentially removing the author side of the market from the analysis.

in Proposition 2 is a generalization to an arbitrary number of platforms of the asymmetric equilibria they derive for two platforms. Hagiu (2006b) analyzes free entry among homogeneous platforms. The simple structure of costs and the additive nature of consumer heterogeneity leads to a unique free-entry equilibrium in which a single platform charges both sides a price equal to marginal cost (zero). He shows that free entry may be less efficient than even monopoly because prices do not reflect indirect network benefits from each side of the market. Our setting—with both fixed and marginal costs and with multiplicative consumer heterogeneity—is sufficiently more complicated that characterizing free-entry equilibrium presents a challenge. We show that free-entry equilibria are generally inefficient but are not able to derive a comparison of the relative efficiency of monopoly and free entry.

The extension to heterogeneous article quality in Section 5.4 is one of the first two-sided-markets papers to incorporate quality. Lerner and Tirole (2006) construct a model in which standard-setting organizations are intermediaries between technology sponsors and end users. Intermediaries obtain perfect signals of the value to end users of submitted technologies and choose whether or not to certify the technologies as being good or bad for end users. Our model differs in that certification is not zero-one but is given by the average quality of published articles; in addition, our intermediaries are profit-maximizing and can commit to a quality threshold. In Morrison and White (2004), intermediaries are regulators that license banks as being sound or unsound. Regulators in different countries differ in the prior probability that they have a viable screening technology. Their model differs from ours in that their intermediaries are benevolent and do not charge licensing fees. Therefore, the central question in our analysis—the level of access prices on the two sides of the market—is not an issue in their paper.

Our monopoly analysis is for a slightly different variant than covered by the general analyses of Armstrong (2006) and Rochet and Tirole (2003, 2006). However, the conclusions are similar (in particular, see Rochet and Tirole 2003). Our analysis of monopoly in Section 3 will thus be brief, and most of our attention devoted to the new analysis of free-entry equilibrium in Section 4.

2. Model

The model has three types of economic agents: journals, authors, and readers. Journals are intermediaries between authors and readers. Journals acquire articles from authors, bundle them into an issue, and distribute them to subscribing readers. The journal expends fixed cost c^A for each article it publishes, reflecting the cost of

processing the article (refereeing, copy editing, typesetting, etc.) and of servicing the author's account. The cost of distributing the issue to a single reader includes a fixed cost c^R plus a variable cost c per article in the issue. The fixed cost c^R includes the cost of servicing the reader's account and any fixed shipping and handling costs. The remaining variable shipping costs, including bandwidth charges for the case of electronic distribution, are embodied in c .

Each author is endowed with a single article. Author i obtains a benefit b_i^A per reader. This term embodies a number of potential benefits. The author may obtain pure enjoyment from being read by an additional reader. Having more readers also enhances an author's career prospects through better name recognition and increased citations, both used as measures for evaluating author talent in hiring, tenure, and promotion decisions. Assume b_i^A is a continuous random variable having distribution function F^A , density f^A , and support $[0, \bar{b}^A]$. Normalize the mass of authors to unity.

Reader k obtains benefit b_k^R per article read. This term embodies the benefit the reader obtains from the information contained in the article. The reader can read as many articles as he likes from the journals to which he subscribes. Assume b_k^R is a continuous random variable having distribution function F^R , density f^R , and support $[0, \bar{b}^R]$. Normalize the mass of readers to unity.

Note we have assumed a fair degree of homogeneity. There are no exogeneous differences among journals. They have identical costs. They may differ in quality but only to the extent they publish different numbers of articles or have different numbers of readers, not in the quality of the articles published nor in the value added in selecting or editing them. Authors differ in the benefits they gain from publishing their articles, but their articles provide identical benefits to readers. That is, articles are of a similar quality.⁴ Readers differ in the benefits they gain from reading a given article, but having the article read provides the same benefit to an author regardless of who is doing the reading. We have also assumed a fair degree of linearity. An author's benefit is linear in the number of readers of his article. A reader's benefit is linear in the number of articles he reads.

⁴A natural question arising in this simple model regards why journals exist in the first place. Why do authors not circumvent the intermediary and circulate their articles directly to readers? First, bundling articles in a journal economizes on the fixed cost, c^R , of serving readers. If $c^R > 0$, it would be prohibitively expensive for the infinitesimal authors to circulate their articles directly to the infinitesimal readers. Second, even if $c^R = 0$, readers may not be able to distinguish between scholarly and non-scholarly material without paying a small cost, and journals may be an economical way of providing that service. Third, as modeled in Section 5.4, a function of journals may be to certify article quality.

Submission fees will be specified on a per-reader basis and subscription fees on a per-article basis.⁵ In particular, we assume journal j charges each author a per-reader submission fee p_j^A times the number of subscribers to journal j , n_j^R , for a total submission fee of $p_j^A n_j^R$.⁶ The journal charges each reader a per-article subscription fee of p_j^R times the number of articles published by the journal, n_j^A , for a total subscription fee of $p_j^R n_j^A$.^{7, 8}

We will impose several additional constraints on the model reflecting industry practice. We will constrain prices p_j^A and p_j^R to be non-negative. Journals may subsidize authors and readers, in that prices may be set below marginal cost, but journals cannot make explicit cash transfers to authors or readers. Following

⁵The results in two-sided-market models are generally sensitive to the assumption of per-transaction or fixed fees. See Rochet and Tirole (2006) for one of the first general analyses incorporating both types of fees.

There are several reasons for specifying prices on a per-reader or per-article basis. First, the assumption reflects the long-run-equilibrium perspective that journals can adjust author prices as the number of readers changes and reader prices as the number of articles changes. This perspective is supported by empirical analysis, available on request from the authors, of a panel of for-profit business and economics journals over the period 1988–2000. Fixed-effects regressions show a positive and statistically-significant relationship between library subscription fees for a journal and the number of articles it publishes in a year. This result holds in ordinary least squares as well as two-stage least squares specifications, in which articles and citations are instrumented with lagged values of these variables. Second, when prices are specified on a per-reader or per-article basis, as discussed in footnote 9, implausible equilibria can be eliminated with the standard refinement of weakly undominated strategies. If prices are instead specified as lump sum, more esoteric refinements such as Ambrus’ (2006) coalitional rationalizability are needed to eliminate implausible equilibria. Third, in realistic extensions considered in Section 5.4 in which an author benefits from the journal’s reputation as measured by the average quality of articles published there, specification of author fees as per-reader or lump-sum turns out to be equivalent. Fourth, the alternative assumption of lump-sum prices is analyzed in an ancillary paper, McCabe and Snyder (2006). The pricing assumption adopted in the present paper allows us to derive a general, analytical characterization of competitive equilibrium rather than being forced to rely on numerical examples as in the ancillary paper.

⁶Since all articles are of equal quality, it makes no difference whether p_j^A is taken to be a submission fee or a fee paid conditional on acceptance since all submitted articles are published.

⁷Equivalently, the subscription fee can be thought of as a function of the number of articles a subscriber actually reads. With linear benefits and fees per article read, a reader who reads any article in a journal reads all of them.

⁸The implicit assumption is that the journal acquires authors and readers simultaneously. Given the assumption of per-transaction prices and the refinement of weakly undominated strategies, the results would be the same if the journal acquired authors and then readers sequentially. See Hagiu (2006a) for an analysis of the sequential variant when the platform’s ability to commit to prices is in question.

industry practice, an author is assumed to be able to publish his article in only one journal, i.e., journals sign exclusive contracts with authors. On the other hand, readers may subscribe to multiple journals.

Players' objective functions are as follows. Journal j 's profit is

$$(p_j^A n_j^R) n_j^A + (p_j^R n_j^A) n_j^R - TC(n_j^A, n_j^R) \quad (1)$$

where $TC(n_j^A, n_j^R)$ is the total cost function

$$TC(n_j^A, n_j^R) = c^A n_j^A + c^R n_j^R + c n_j^A n_j^R. \quad (2)$$

If author i submits his article to journal j , he obtains net surplus

$$n_j^R (b_i^A - p_j^A). \quad (3)$$

Author i will submit his article to the journal j providing the highest surplus (3) as long as this surplus is positive. If (3) is negative for all j , he will not submit his article to any journal. If reader k subscribes to journal j , he obtains net surplus

$$n_j^A (b_k^R - p_j^R). \quad (4)$$

Since readers can subscribe to multiple journals simultaneously, reader k will subscribe to any journal j for which (4) is non-negative.

In the next several sections, we will analyze market structures for journals ranging from monopoly to free entry. The next section starts with the simplest market structure, monopoly, allowing us to develop the model further in this simple setting.

3. Monopoly

A single, profit-maximizing monopoly journal j sets prices p_j^A and p_j^R . Author i submits his article to the journal if his surplus given in expression (3) is non-negative, or, rearranging, if $b_i^A \geq p_j^A$. Author demand for the journal is thus $n_j^A = 1 - F^A(p_j^A)$. Similarly, reader demand is $n_j^R = 1 - F^R(p_j^R)$.⁹

⁹The equations for author and reader demand implicitly rule out the possibility that the market breaks down, with each side of the market anticipating no one on the other side will participate. The refinement of weakly undominated strategies, which we will adopt throughout the paper, is sufficient to rule out market breakdown and ensure that the stated equations uniquely represent demand. To see this, take the example of author demand. Given that author prices are specified as per-reader, it is a weakly dominant strategy for authors to submit to a monopoly journal as long as his net benefit per reader is positive. If no readers subscribe, the author pays nothing so is no worse off than if he did not submit. If a positive measure of readers subscribe, the author gains more from submitting than not.

The first-order condition from maximization of journal profit (1) with respect to p_j^A , for example, is

$$\frac{dn_j^A}{dp_j^A} n_j^R (p_j^A + p_j^R) + n_j^A n_j^R - MC^A \frac{dn_j^A}{dp_j^A} = 0, \quad (5)$$

where $MC^A = dTC(n_j^A, n_j^R)/dn_j^A = c^A + cn_j^R$ is the marginal author cost. The first-order condition can be rearranged in the form of a Lerner index:

$$L^A \equiv \frac{n_j^R p_j^A - MC^A}{n_j^R p_j^A} = \frac{1}{|\epsilon_j^A|} - \frac{n_j^A n_j^R p_j^R}{n_j^A n_j^R p_j^A}, \quad (6)$$

where $\epsilon_j^A \equiv (dn_j^A/dp_j^A)(p_j^A/n_j^A)$ is the own-price elasticity of author demand. The Lerner index L^A is defined to be the percentage markup of the total author fee $n_j^R p_j^A$ over marginal cost MC^A . Equation (6) characterizes the monopoly price as long as the constraint $p_j^A \geq 0$ does not bind; if (6) would imply a negative price, then the solution is $p_j^A = 0$. The corresponding first-order condition and expression for the Lerner index for reader price p_j^R are analogous, simply interchanging superscripts.

Equation (6) implies that the journal prices as would a multiproduct monopolist producing complementary goods, here, authors and readers. The journal shades the submission fee $n_j^R p_j^A$ down somewhat from the single-product Lerner index formula to take account of the effect that increasing the number of articles increases the number of readers, on whom the journal may earn a margin. Similar reasoning holds for the subscription fee $n_j^A p_j^R$. The greater is the revenue earned from readers, $n_j^A n_j^R p_j^R$, relative to that earned from authors, $n_j^A n_j^R p_j^A$, the more the journal gains from subsidizing authors to increase reader demand.

Equation (6) indicates that a monopoly journal may charge strictly positive prices for both authors and readers. This will indeed be the case if both sides of the market are symmetric or nearly so. Charging positive prices allows the monopolist to extract surplus from both sides of the market. For the monopolist to wish to charge a non-positive price to one side of the market, the two sides of the market must be sufficiently asymmetric. The monopolist would then subsidize the low-value side of the market in order to extract more surplus from the high-value side. Open access will thus only emerge in equilibrium with a monopoly journal if the author side of the market is sufficiently high-value relative to the reader side. If the two sides are perfectly symmetric, a monopolist would never adopt open access. This is true even if readers are costless to serve ($c^R = c = 0$) because of the Internet or other technology.

An example demonstrates the possibility that a monopolist will set a zero price on one side of the market if the two sides are sufficiently asymmetric. Suppose $c^A = c^R = c = 0.1$, b_i^A is uniformly distributed on $[0, \bar{b}^A]$, and b_k^R is uniformly distributed on $[0, \bar{b}^R]$. If $\bar{b}^A = \bar{b}^R = 1$, then the equilibrium monopoly prices are $p_j^A = p_j^R = 0.43$, monopoly profit is 0.13, and social welfare is 0.32. As \bar{b}^A is increased above a threshold of 2.5, the monopoly switches from charging both positive prices to open access (i.e., $p_j^R = 0$). If c^R is reduced from 0.1 to 0 (perhaps capturing Internet distribution), the threshold value of \bar{b}^A above which the monopoly journal adopts open access falls from 2.5 to 2.

To judge the efficiency of the monopoly outcome, it can be compared to the second best, i.e., the outcome maximizing the sum of consumer and producer surplus subject to a break-even constraint for the journal. We will omit the details, referring the reader to similar analysis in Sections 2.2 and 5 of Rochet and Tirole (2003). The main finding is that, while the overall price level may be lower in the second best, the structure of author relative to reader prices can be similar between the second best and monopoly equilibrium. If author and reader sides of the market are symmetric, author and reader prices will be equal in the second best, just as in the monopoly equilibrium. For prices to be unequal, there has to be some asymmetry between the two sides. For example, for open access to be socially efficient, it is still necessary for the author side to be sufficiently important. In the second best, “importance” is measured by both the relative revenue generated by the side of the market in question as well as the relative consumer surplus that flows as a positive externality from the other side of the market. Analogously, for free submission to be socially efficient, the reader side must be sufficiently important.

Return to the numerical example introduced in this section with $c^A = c^R = c = 0.1$, and with b_i^A and b_k^R uniformly distributed on $[0, \bar{b}^A]$ and $[0, \bar{b}^R]$, respectively. If $\bar{b}^A = \bar{b}^R = 1$, second-best prices are $p_j^A = p_j^R = 0.17$. As \bar{b}^A is increased above a threshold of 1.4, the second best switches from both positive prices to open access. While second-best prices are lower than monopoly prices, and while the threshold for open access is lower, the numerical example shows that prices in the second best and the monopoly equilibrium can have a similar relative structure.

4. Free Entry

In this section, we analyze equilibrium when homogeneous journals can freely enter. This case is important to analyze for two reasons. First, it will complement the

monopoly analysis from the previous section, providing the other extreme of a continuum of market structures. The case of moderate competition between a limited number of differentiated journals could be expected to fall somewhere in between. Second, while reputational capital and the complicated bundling strategies may serve to differentiate incumbent journals and raise entry barriers in the short run (Dewatripont *et al.* 2006), there is enough evidence of long-run movements in the journal market that the case of free entry is worth considering.^{10,11}

Suppose there are an unlimited number of homogeneous journals that are potential entrants in the market. Journals have no fixed entry costs, though as before they have fixed costs c^A of serving authors and c^R of serving readers. Let $j = 1, \dots, J$ index active journals, i.e., journals serving a positive mass of each of authors and readers. Active journals set prices p_j^A and p_j^R simultaneously. A free-entry equilibrium is an author/reader price pair for each active journal satisfying two properties: first, each active journal earns non-negative profit and, second, no inactive journal can choose prices that would allow it to enter and earn positive profit.¹²

Recall the assumption from Section 2 that while readers can subscribe to multiple journals, authors must choose a single journal to which to submit. In the parlance of the two-sided-markets literature, authors singlehome and readers multihome. This asymmetry between the two sides of the market will play a key role in the analysis of free-entry equilibrium, as it did in the analyses of competing platforms in Armstrong (2006) and Rochet and Tirole (2003, 2006). Journals compete aggressively for authors since authors can only sign up with one journal. Journals do not similarly compete for readers. A reader will subscribe to any journal j for which his surplus, equation (4), is non-negative, a condition which is independent of other journals' prices or quantity of authors or readers.

Journals compete for authors by charging low author prices (providing authors with a direct benefit) and low reader prices (providing authors with an indirect

¹⁰The Berkeley Electronic Press has created twelve new series; the American Economic Association is developing four new field journals; the *Journal of the European Economic Association* was created by a wholesale movement of editors from the *European Economic Review* after a dispute with the publisher; McCabe and Snyder (2006) document 22 new, refereed, open-access journals in the fields of economics and business.

¹¹Capital requirements may be relatively lower for journals than many other markets. Even if it is argued that other capital requirements are substantial, external sources of revenue, discussed in Section 5.3, may be available to subsidize entry.

¹²This equilibrium concept is related to Baumol, Panzar, and Willig's (1982) contestable market. The difference is that their one-sided market setting, all active firms necessarily shared the same price vector, whereas two active journals can have two different price vectors in our setting.

benefit through the increase in the number of readers). Competition in free-entry equilibrium is intense, dissipating all potential profits, as the following proposition states. The proof of Proposition 1 and all subsequent propositions is provided in the Appendix.

Proposition 1. *In a free-entry equilibrium, each journal earns zero profit.*

In any outcome in which a journal j earns positive profit, there is a potential entrant willing to undercut j 's prices slightly, thereby capturing all of j 's demand and almost all of j 's profit for itself. If $p_j^A > 0$, the entrant can capture j 's authors directly by undercutting p_j^A slightly. If $p_j^A = 0$, the entrant cannot undercut p_j^A since negative prices are not allowed. The entrant can undercut p_j^R slightly, providing a larger readership than j and thus making the journal more attractive to authors.

The next three propositions provide a characterization of free-entry equilibrium for various configurations of the cost parameters. Proposition 2 treats the case in which $c^R > 0$. Economies of scale in bundling articles arise when $c^R > 0$. Fixing the number of articles a reader reads, the fewer journals the articles are divided among, the fewer times the fixed reader cost c^R needs to be expended. Thus, since the support of author and reader types are bounded (by \bar{b}^A and \bar{b}^R , respectively) there will be a finite number of active journals in equilibrium.

Proposition 2 shows that these active journals partition the space of authors and readers. The proof of the proposition begins with a lemma (Lemma 1), which works out the details of the argument that no two active journals can charge the same pair of author-reader prices if $c^R > 0$. Otherwise a journal could enter, slightly undercut one or the other price, capture the two journals' demand, but economize on cost because the authors would be collected in a single journal so only one fixed cost c^R per reader would have to be expended per reader rather than two. Thus active journals must charge different prices; in particular, considering any two journals, one must charge a higher author price and a lower reader price than the other. If not, one of the two journals would have to be charging higher prices to both authors and readers, and this journal would obtain no demand.

It follows that if $c^R > 0$, the J active journals can be ordered beginning with the one charging the highest author price but lowest reader price at one extreme (labeled journal 1), down to the journal charging the lowest author price but highest reader price (labeled journal J). Journal 1 serves the most readers since it has the lowest reader price. It serves the interval of the highest-value authors since they have the highest marginal rate of substitution between readers and fees. If these highest-value authors would not submit to journal 1, no author types would, and journal 1 would be inactive. As the journal index j increases, lower intervals of

author types are served and smaller numbers of readers are served. If $J > 1$, some readers end up subscribing to several journals. A reader who subscribes to journal j also subscribes to journals $1, 2, \dots, j - 1$. Formally, we have the following proposition.¹³

Proposition 2. *Suppose $c^R > 0$. In a free-entry equilibrium, there exists an ordering of the $n \geq 0$ active journals $j = 1, \dots, J$, a partition of author types*

$$0 \leq B_J^A < B_{J-1}^A < \dots < B_2^A < B_1^A < B_0^A = \bar{b}^A, \quad (7)$$

and a partition of reader types

$$0 \leq B_1^R < B_2^R < \dots < B_{J-1}^R < B_J^R < \bar{b}^R \quad (8)$$

such that journal j serves all author types in the interval (B_j^A, B_{j-1}^A) and all reader types in the interval $(B_j^R, \bar{b}^R]$. Author prices are strictly decreasing and reader prices are strictly increasing in index j : for all $j = 1, \dots, n$, $p_j^A < p_{j-1}^A$ and $p_j^R > p_{j-1}^R$.

Proposition 2 implies that if $c^R > 0$, there will be at most one open-access journal. It would serve the most readers of any journal since of course all readers would subscribe. It would serve the authors who care the most about wide dissemination. Symmetrically, the proposition implies that there will be at most one free-submission journal, serving the interval of authors who care the least about wide dissemination, subscribed to by only an interval of the highest-value readers.

If $c^R = 0$, economies of scale in bundling articles disappears. Competition to capture each author type leads to niche journals. Each niche journal tailors its combination of author fees and readership (which depends in turn on reader fees) to maximize each author type's utility subject to a break-even constraint for the journal.

Proposition 3. *Suppose $c^R = 0$. Each author type b_i^A that is served is charged prices $p^A(b_i^A)$ and $p^R(b_i^A)$ maximizing this type's gross surplus subject to a break-*

¹³Technically, Propositions 2 and 3 do not need to hold on sets of author/reader types of zero measure. We omit the modifier “for almost all types” to make the propositions more succinct, but the proofs incorporate this technicality.

even constraint for the journal:

$$p^R(b_i^A) = \begin{cases} \operatorname{argmax}_{p_j^R} \{[1 - F^R(p_j^R)](b_i^A + p_j^R - c)\} \\ \text{subject to } p_j^R \in \left[0, \frac{c^A}{1 - F^R(p_j^R)} + c\right] \end{cases} \quad (9)$$

$$p^A(b_i^A) = \frac{c^A}{1 - F^R(p^R(b_i^A))} + c - p^R(b_i^A). \quad (10)$$

Intervals of author types over which $p^A(b_i^A)$ and $p^R(b_i^A)$ vary are served by a continuum of journals, and intervals over which these prices are constant are served by an indeterminate number of journals (any number between zero and a continuum). Author type b_i^A is served if and only if

$$[1 - F^R(p^R(b_i^A))][b_i^A + p^R(b_i^A) - c] \geq c^A. \quad (11)$$

It is easy to characterize the special case of costless journal production. The following proposition is a straightforward corollary of Proposition 3.

Proposition 4. *Suppose $c^A = c^R = c = 0$. The number of active journals is indeterminate: there can be any number between one and a continuum. Active journals charge the same prices $p_j^A = p_j^R = 0$. All authors and readers are served.*

Propositions 3 is related to Proposition 2, showing what happens to the results in Proposition 2 in the limit as $c^R \rightarrow 0$. The number of active journals increases, providing an increasingly fine partition of author types that are increasingly well tailored to the preferences of each individual author.

Return to the numerical example from Section 3 in which $c^A = c^R = c = 0.1$ and b_i^A and b_k^R are uniformly distributed on $[0, 1]$. This parameter configuration is covered by Proposition 2. Figure 1 depicts the free-entry equilibria. There is a continuum of equilibria, all involving one active journal. The equilibria range from an author/reader pair of $(0.00, 0.35)$ (note involving free submission) to $(0.20, 0.14)$. A grid search revealed no equilibria for these parameters with two active journals.

If all the parameters in this numerical example are kept the same but c^R is reduced from 0.1 to 0, then Proposition 3 applies. A continuum of journals operates with equilibrium prices given in Figure 2. To show the full range of possibilities, the figure also expands the support of author types by taking b_i^A to be uniformly distributed on $[0, 2]$ rather than $[0, 1]$. The journals serving the

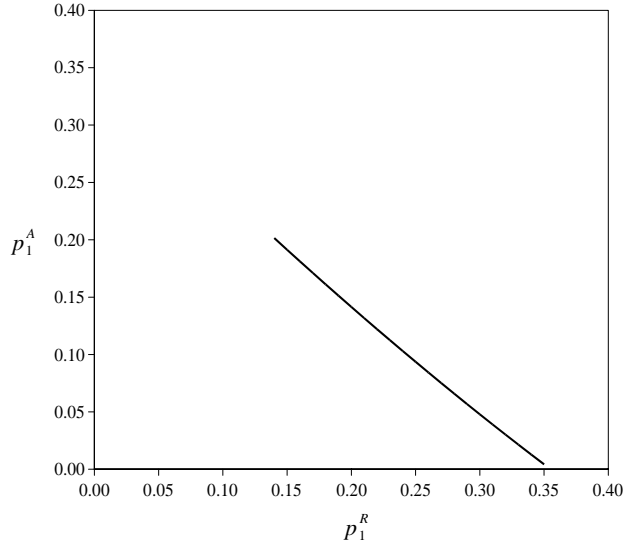


Figure 1: Set of free-entry equilibria in numerical example with $c^A = c^R = c = 0.1$ and b_i^A and b_k^R uniformly distributed on $[0, 1]$. Displayed are prices charged by the single active journal.

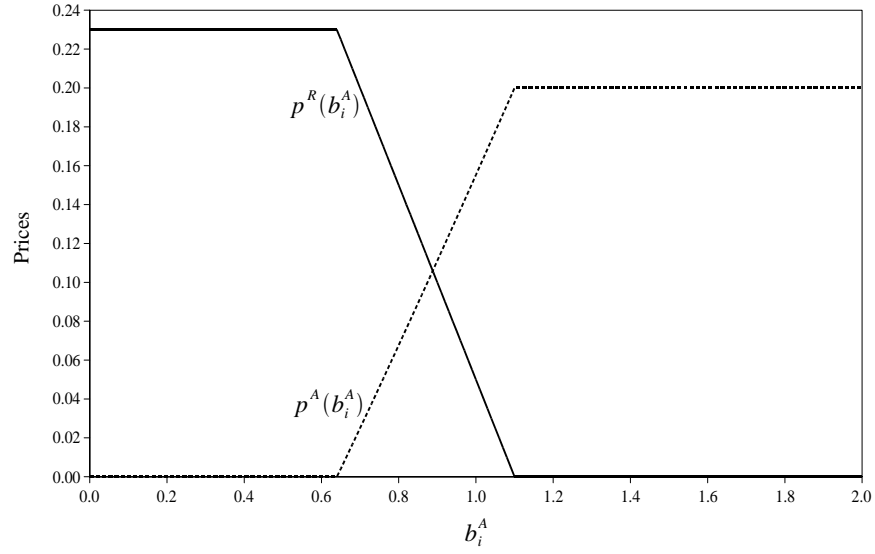


Figure 2: Free-entry equilibrium in numerical example with $c^A = c = 0.1$, $c^R = 0$, b_i^A uniformly distributed on $[0, 2]$, and b_k^R uniformly distributed on $[0, 1]$. Involves a continuum of journals.

lowest-value authors adopt free submission and high reader fees. The number of such journals is indeterminate, any number between one and a continuum. Journals serving intermediate types charge positive prices to both authors and readers. There are a continuum of different journals in this range. Journals serving the highest author types adopt open access, deriving their revenue from high submission fees. Again, the number of such journals is indeterminate.

Figure 2 depicts a case in which the free-entry equilibrium involves some open-access journals. Journals serving authors with types $b_i^A \geq 1.1$ offer free subscriptions. Proposition 5 provides additional sufficient conditions for open access to emerge in equilibrium. Before presenting the proposition, some notation is in order. Recall author types b_i^A are contained in $[0, \bar{b}^A]$, implying \bar{b}^A is an upper bound on author types. Let \underline{b}^A be the greatest lower bound on the support of author types (this will exceed 0 if types in $[0, \underline{b}^A]$ have zero measure).

Proposition 5. *The following are alternative sets of sufficient conditions for some journal to adopt open access in the free-entry equilibrium.*

Set (i): $c^A = c^R = c = 0$.

Set (ii): $c^R > 0$ and

$$\underline{b}^A > c^A + c^R + c + \max_{p_j^R \in [0, \bar{b}^R]} \left\{ p_j^R \left[\frac{1}{\eta^R(p_j^R)} - 1 \right] \right\}, \quad (12)$$

where $\eta^R(p_j^R) = p_j^R f^R(p_j^R) / [1 - F^R(p_j^R)]$ is the absolute value of the elasticity of reader demand.

Set (iii): $c^R = 0$ and

$$\bar{b}^A > c + \max_{x \in [0, \bar{b}^R]} \left\{ \frac{[1 - F^R(x)]x}{F^R(x)} \right\}. \quad (13)$$

We already saw the sufficient conditions in set (i) in Proposition 4. The intuition behind the sufficient conditions in set (ii) is that if authors have sufficiently high values for readers, they would always be willing to switch to an entrant charging a higher author price but a lower reader price (thus having greater readership) unless these authors were presently served by an open-access journal, which maximizes readership. Set (iii) is a sufficient condition for the maximization program (9) to have the solution $p^R(b_i^A) = 0$ for author types in a neighborhood of the

highest value, \bar{b}^A . If so, this neighborhood of high-value authors would be served by an open-access journal or journals.

To measure the social efficiency of free-entry equilibrium, we will analyze a variant of the second best, namely the second best with J active journals, where J is set to maximize social welfare subject to all active journals' breaking even. Free-entry equilibria are generally fall short of this benchmark. For example, consider the numerical example in Figure 1. One of these equilibria, the one with author-reader price vector $(0.17, 0.17)$, is second-best efficient conditional on there being one active journal. However, social welfare is 38 percent higher in the second-best outcome with two active journals. Two journals can better serve the range of author and reader types than one. This second-best outcome with two journals is not a free-entry equilibrium because it is vulnerable to entry.

Free-entry equilibrium in the case in which $c^R = 0$ are not generally second-best efficient either. While the number of active journals (a continuum) is efficient, their prices generally are not. The prices are set to maximize the targeted author's consumer surplus and do not directly take into account the consumer surplus of readers. Consider the numerical example in Figure 2. It is second-best efficient for authors of types $b_i^A \in [0.2, 2.0]$ to be served by open-access journals. They could be charged high enough author prices to subsidize zero reader prices and still have the journals break even. However, as the figure shows, the free-entry equilibrium does not involve open access for $b_i^A \in [0.20, 1.09]$.

Our results on the inefficiency of free-entry equilibrium echoes Hagiu (2006). In a simpler setting with additive consumer heterogeneity and zero costs, Hagiu shows that free-entry equilibrium may be less efficient even than monopoly.

5. Extensions

In this section, we will extend the basic analysis in several directions to try to capture some further institutional details of the journal market in practice.

5.1. Endogenous Reader Cost

The analysis so far has taken the cost structure as given. In practice, costs may depend on the pricing regime. In particular, open access frees the journal from having to keep track of readers and process their accounts, leading to lower reader costs. Indeed, in an online-journal environment, open access can eliminate fixed reader costs entirely (in a print-journal environment, delivering the physical copy to the reader may still involve a fixed cost).

We will model the possibility that open access reduces fixed reader costs in the following way.¹⁴ We will continue to take cost parameters c^A and c as given but suppose that the fixed reader cost depends on the pricing regime, equaling $c^R > 0$ if $p_j^R > 0$ and 0 if $p_j^R = 0$. That is, the journal has to pay the fixed cost of creating and processing a reader's account if it wants to collect fees from him. This specification does not rule out the possibility that Internet distribution involves bandwidth costs, which would appear as a positive cost per download $c > 0$ independent of the number of readers who are doing downloading.

It is clear that endogenizing costs in this way increases the range of parameters for which open access would emerge with a monopoly, in the second best, and in free-entry equilibrium. The next proposition provides sufficient conditions under which open access emerges in free-entry equilibrium with endogenous costs as modeled in this section.

Proposition 6. *Suppose adopting open access reduces the fixed reader costs from $c^R > 0$ to 0. If (13) holds, some journal adopts open access in free-entry equilibrium.*

The proof is immediate from Proposition 5. By Proposition 5, condition (13) ensures that some journal adopts open access in free-entry equilibrium for $c^R = 0$. But if costs are endogeneous as modeled here, $c^R = 0$ is indeed the relevant reader fixed cost for an open-access journal, so (13) is still the relevant condition guaranteeing open access. It should be emphasized that Proposition 6 provides sufficient conditions for open access; open access may emerge when costs are endogeneous in a broader range of cases as well.

Endogenizing cost may have a substantial effect on the propensity to adopt open access. Returning to the numerical example in which $c^A = c^R = c = 0.1$ and b_i^A and b_k^R are uniformly distributed on $[0, 1]$, Figure 1 shows that if costs are not endogeneous, none of the range of equilibria with one active journal exhibit open access. If endogeneous costs are added to this example—i.e., if adopting open access is assumed to reduce c^R from 0.1 to 0—it can be shown using a grid search

¹⁴To the extent that many subscriptions are mediated through libraries, the model to follow may exaggerate the cost savings from open access. Journals may only need to pay the fixed cost of processing each library's account rather than the numerous readers each library may represent. Still, open access may lead to some cost savings, eliminating the need to negotiate with each library over price as is done by several commercial publishers and eliminating the cost of processing each library's account. Further, open access may be more convenient for readers, saving them from having to pass through login screens or library gateways. This additional convenience benefit could be modeled along the lines of reader-cost savings.

that there is a unique free-entry equilibrium with one active journal and the active journal adopts open access in this equilibrium.

5.2. Non-Profit Journals

The paper has so far considered profit-maximizing journals. This section takes up the case of non-profit journals, an important case to consider because non-profits make up a substantial portion of the journal market, most notably professional-association journals. The case is more complicated because non-profits may have a variety of different possible objective functions, but we can draw out some of the implications of our analysis so far and can make some additional general points.

Consider the case in which the non-profit journal is a monopolist. Assuming the journal's objective is to maximize social surplus subject to a break-even constraint, then the equilibrium would be equivalent to the second-best social optimum analyzed at the end Section 3. Other possibilities include that the journal is dedicated to open-access and either maximizes profit or social surplus subject to this constraint.¹⁵

One must be careful to distinguish between the profit and non-profit cases to understand the effect of monopoly power on the pricing regime. In the case of a for-profit monopolist, its monopoly power can generally be expected to result in higher markups compared to the competitive case and thus fewer cases in which a free-submission regime on the one hand or an open-access regime on the other might be observed. Monopoly power for a non-profit will likely have the opposite effect. The non-profit can use monopoly rents to subsidize its particular objectives, whether surplus maximization, zero prices on one or the other side of the market, etc. If, for example, the non-profit journal is interested in promoting open access, it can use its monopoly rents to subsidize low subscription fees. Competitive pressures may reduce the journal's freedom to pursue particular objectives.

Next consider the case in which a non-profit journal (journal 1) competes alongside profit-maximizing journals in a free-entry equilibrium. To make the discussion concrete, suppose that journal 1's objectives are targeted at open access. More precisely, it maximizes author surplus subject to an open-access constraint ($p_1^R = 0$) and a break-even constraint. (The analysis is similar for other specifications of journal 1's objective function.) Suppose that otherwise journal 1 is identical to other journals in terms of costs and the value it provides customers.

¹⁵The Public Library of Science (PLOS) journals in biomedicine, founded by Nobel-prize-winner Harold Varmus, may fit this model.

It is immediate that the non-profit journal is competitively viable if and only if there exists a free-entry equilibrium among profit-maximizing journals (as characterized by Propositions 2 through 4) involving open access. Thus, Proposition 5, which provides sufficient conditions for open access to emerge in free-entry equilibrium with profit-maximizing journals, also provides sufficient conditions for the non-profit journal to be competitively viable. It might be argued that the presence of the non-profit journal may help competitors coordinate on an equilibrium with an open-access journal if such an equilibrium exists among multiple equilibria. But aside from this tenuous equilibrium-selection argument, the presence of a non-profit journal makes little difference in the free-entry context. Competitive pressures limit a non-profit's ability to pursue idiosyncratic objectives.

5.3. External Revenue Source

The analysis has assumed that the journal's only revenue sources are author and reader fees. In practice, journals sometimes gain additional revenue from a variety of sources including advertising, registration fees for affiliated conferences, discriminatory fees charged to non-scholar practitioners, a subsidy from the sponsoring society or host institution, or a grant from a foundation.¹⁶

We can model this external revenue simply by supposing that journal j has a lump-sum subsidy that it can use to fund operations. It is immediate that this subsidy does not affect equilibrium with profit-maximizing journals for any market structure—monopoly or free entry—because lump sums will not affect their marginal decisions.

A subsidy may affect the second best with a single active journal or, equivalently, the pricing policy of a non-profit monopoly journal dedicated to maximizing social welfare. A subsidy may affect the viability of a non-profit journal dedicated to open access in competition against profit-maximizing journals in a free-entry equilibrium.

Consider the second best with a single active journal, analyzed at the end of Section 3. The provision of a lump-sum subsidy would tend to reduce the overall level of both author and reader prices, increasing the range of parameters for which there is open access in the second best. Consider the viability of a non-profit journal dedicated to open access in competition against a profit-maximizing

¹⁶Some of these sources are more important in fields other than business and economics, but even here they are present in some cases (the *American Economic Review* accepts some advertising, the *Journal of Investment Management* uses conference registration fees to subsidize journal operations, *Economics Bulletin* relies on in-house computer support from its host university, etc.).

journal. The provision of a subsidy to the non-profit journal will clearly increase the range of parameters for which it is viable.¹⁷

5.4. Quality Certification

We have so far modeled quality considerations in a relatively spare way. From the authors' perspective, a high-quality journal is a widely read one. From the readers' perspective, a high-quality journal contains many articles. The spare model provides a useful start because it connects with much of the existing literature on two-sided markets and provides a simple setting to fix basic ideas. However, a richer model is needed to capture further quality considerations that are important for journals. Research is not homogeneous; some articles are better than others. Given articles are of heterogeneous quality, some mechanism is needed to certify quality. Readers can use this information to economize on reading time by focusing on the best research or to help weigh the merits of different evidence and methodologies. Employers can use this information to help judge author talent in hiring, tenure, and promotion decisions. Journals provide this certification mechanism. Quality certification is more important for journals than many of the other markets to which the two-sided-market model has been applied, including telecommunications and credit cards.

In this section, we will modify the model used so far by having articles differ in quality, by having authors benefit from publishing in a high-reputation journal—where reputation is measured by the average quality of articles published in equilibrium—and by having readers benefit from the aggregate quality of articles in the journal.

Formally, suppose author i is endowed with an article of quality $q_i \in [0, \bar{q}]$. Author i derives net surplus $b_i^A Q_j - n_j^R p_j^A$ from publishing in journal j , where Q_j

¹⁷External revenue sources may change the game for authors and readers as well. To the extent that an author can rely on his home institution or grant funder to pay part of the submission fee, his marginal rate of substitution between readership and fees reflected in b_i^A will increase. If the funder can also dictate the journal to which the author must submit his article, then our original model applies with the parameters on the authors' side reinterpreted as reflecting the funders' valuations. (This possibility is of current policy interest, with at least 23 major international funding organizations providing line items for increased submission fees according to the website of open-access publisher BioMed Central, www.biomedcentral.com, downloaded May 30, 2006, and with organizations such as the U.S. National Institutes of Health debating whether funded authors should be required to submit to open-access journals.) To the extent that a reader can rely on his home institution's library to pay subscription fees, the reader's parameters need to be reinterpreted as an aggregation of the underlying demand of the library's patrons.

is the average quality of articles published in journal j , which we will sometimes refer to as the journal's reputation. The model thus departs from the stark assumption that authors care about the number of readers for the stark assumption that authors care about a certification benefit independent of the number of readers. In practice, authors may care about both, but considering each separately simplifies the analysis. Assuming authors care about certification independent of the number of readers can be justified by assuming that the certification appears on the author's curriculum vitae, and the number of people reading the author's curriculum vitae may be independent of the number of people reading the journals listed there. Assume b_i^A and q_i are random variables with joint distribution $F^A(b_i^A, q_i)$. Reader k 's net surplus from journal j is $n_j^A(b_k^R Q_j - p_j^R)$. Readers benefit from the total quality of research in journal j , equal to the number of articles n_j^A times average quality per article Q_j . As before, b_k^R is distributed according to $F^R(b_k^R)$. As before, we take author prices to be per-reader and reader prices to be per-article.¹⁸ Journals commit to a quality standard s_j , accepting a submitted article if and only if $q_i \geq s_j$.

Begin with an analysis of the monopoly case. Given monopoly journal j sets quality standard s_j , the average quality of articles published in the journal implicitly solves

$$Q_j^m = \frac{\int_{s_j}^{\bar{q}} \int_{\hat{b}_j}^{\bar{b}^A} q_i dF^A(b_i^A, q_i)}{\int_{s_j}^{\bar{q}} \int_{\hat{b}_j}^{\bar{b}^A} dF^A(b_i^A, q_i)}, \quad (14)$$

where $\hat{b}_j = n_j^R p_j^A / Q_j^m$ is the valuation of the marginal author (among those whose quality meets the journal's standard) who is indifferent between submitting and not.

Comparative statics results are generally ambiguous. Consider the effect of an increase in the quality standard on the subscription price, $\partial p_j^R / \partial s_j$. An increase in s_j increases average article quality Q_j by cutting off more of the lower tail of articles. This may increase or decrease p_j^R depending on the elasticity of reader demand with respect to Q_j , which in turn depends on $F^R(b_k^R)$. An increase in Q_j also affects n_j^A . The direction is ambiguous: fewer authors are eligible for publication, but more authors with high q_i but low b_i^A may be induced to submit

¹⁸Now that authors' benefits are independent of the number of readers, the assumption that author prices are per-article no longer makes a difference. We maintain the accounting convention to preserve the notation from before.

because of the journal's higher reputation. The change in n_j^A will have an indirect effect on p_j^R since the marginal revenue from readers depends on n_j^A .

Next, turn to an analysis of free-entry equilibrium. The broad insights from the analysis of free entry without quality certification in Section 4 carry over to the case of quality certification. On the one hand, competition for authors drives the equilibrium toward niche articles that serve the interests of individual author types. On the other hand, economies of scale in bundling articles together that arise when $c^R > 0$ limit how refined the partition of author types can be.

The specific results in Propositions 2 and 3 may or may not carry over to the case of quality certification. If $c^R > 0$, then a finite number of journals will partition the set of authors types. Since authors' types are two-dimensional (q_i and b_i^A), the subset of types served by a particular journal need not be, as it is in Proposition 2, convex. Nor is the nice ordering of author and reader prices from Proposition 2 necessarily preserved, since a two-dimensional set of types does not generally have a nice ordering.

If $c^R = 0$, any economies of scale in bundling articles disappears, leaving only the force toward serving the interests of individual author types. Similar to Proposition 3, there is a continuum of journals in the free-entry equilibrium, each maximizing the net surplus of the targeted author type. The details of the equilibrium are slightly different than in Proposition 3. Given that authors care about quality certification rather than the number of readers, there can be free-entry equilibria in which journals earn positive profit. Authors may happen to sign up with journals that earn a profit from high reader fees that have low readerships. Entry by another journal with lower reader fees and a greater expected readership would not strictly tempt the author to jump to the entering journal given that the author is served in equilibrium by a journal with a quality standard perfectly matched to his own and at the lowest possible submission price.¹⁹ Proposition 7 characterizes the full range of equilibria, zero profit and positive profit.

Proposition 7. *Assume $c^R = 0$. In all free-entry equilibria of the quality-certification model, there is a continuum of journals, with each quality q_i served by a different journal or journals.*

¹⁹If, in addition to caring about certification, authors care slightly about number of readers, say having lexicographic preferences over quality certification first and readership second, then free-entry equilibria with positive journal profits would be eliminated, and only the one with low subscriber fees and zero profits would remain.

Case (i): If the following inequality is satisfied for some p_j^R ,

$$[1 - F^R(p_j^R/q_i)](p_j^R - c) - c^A \geq 0, \quad (15)$$

then there exists a free-entry equilibrium in which a journal charges $p^A(q_i) = 0$ and $p^R(q_i)$ equal to any p_j^R satisfying (15). Profit for journals of quality q_i is given by the left-hand side of (15) and may be positive. All authors of quality q_i submit regardless of b_i^A .

Case (ii): If (15) is not satisfied for any p_j^R , then prices in the free-entry equilibrium satisfy

$$p^R(q_i) = \operatorname{argmax}_{p_j^R \geq 0} \{ [1 - F^R(p_j^R/q_i)](p_j^R - c) \} \quad (16)$$

$$p^A(q_i) = c - p^R(q_i) + \frac{c^A}{1 - F^R(p^R(q_i)/q_i)}. \quad (17)$$

Journals of quality q_i earn zero profit. Authors of quality q_i and value for certification

$$b_i^A \geq \frac{1}{q_i} \{ [1 - F^R(p^R(q_i)/q_i)][c - p^R(q_i)] + c^A \} \quad (18)$$

submit their articles.

One contrast between Proposition 7 and its analogue without quality certification, Proposition 3, is that the relevant author type targeted by journals is q_i rather than b_i^A . A journal or journals serving type q_i cannot further tailor their offerings to suit only particular b_i^A types within that quality category. A policy of attracting low- b_i^A authors within a set of authors of quality q_i —say by charging a lower author price—would also attract high- b_i^A authors. Varying the reader price does not help target b_i^A types because authors do not care directly about the number of readers.

6. Conclusion

We analyzed equilibrium in market structures ranging from monopoly to free entry. The monopoly case is relevant if it is thought that reputational capital or complex bundling strategies used by incumbents are sufficient entry barriers to afford the

journal some market power. A monopoly journal would typically charge markups over marginal cost to both sides of the market, resulting in both significant submission fees and subscription fees, unless there is considerable asymmetry between the two sides. If, for example, the reader benefits dominate author benefits, either because there are many more readers than authors or because the given number of readers gain a high benefit per article read, then the monopolist will lower submission fees to attract more authors and extract more revenue from readers. In the extreme case, the monopolist will adopt a free submission policy. On the other hand, if author benefits dominate reader benefits, the monopolist will shade subscription fees down, adopting open access (free subscriptions) if the asymmetry is extreme.

At the other extreme, the nature of the free-entry equilibrium hinged on the value of the fixed cost of serving a reader, c^R . This result is important given that new digital technologies may reduce this cost, in some cases to zero. If $c^R = 0$, there are no economies of scale in journal operation. The stringent competition to sign up authors leads to the entry of a continuum of journals, each precisely targeting a different author type by offering a submission-fee/subscriber-base bundle that maximizes that type's surplus subject to a break-even constraint for the journal. This maximization does not necessarily result in a journal's offering free submission, because some author types may be willing to pay more for a journal with lower subscription fees and thus more readers. Indeed, journals targeting the authors with the highest benefit per reader b_i^A may offer open access and relatively high submission fees, as we saw in the example in Figure 2. If $c^R > 0$, there are economies of scale in journal operations in that bundling more articles together in fewer journals saves the duplication in the cost of serving readers c^R . The free-entry equilibrium in this case involves a finite number of journals partitioning the author types. The first journal serves the highest value authors with the highest author prices but lowest reader prices; the next journal serves the next lower interval of author types with a lower author price but higher reader price, and so on.

We analyzed an extension in which articles differ in quality and authors care about being certified by a journal that publishes articles of high average quality rather than the number of readers. The most interesting results emerged from an analysis of how the addition of quality certification changed the free-entry equilibrium. With authors having a two-dimensional type (article quality as well as value of publishing), the partition of author types in the $c^R > 0$ case with a finite number of active journals is more difficult to characterize. If $c^R = 0$, however,

we can precisely characterize free-entry equilibrium as involving a continuum of journals, each targeting a different article quality q_i .

Non-profits are important players in the journal market, and we devoted a section to their analysis. Regardless of its idiosyncratic objectives—maximizing readership, maximizing the surplus of affiliated scholar members, etc.—a non-profit journal can exploit any market power it has or any other source of rent such as an external grant, advertising revenue, or cross subsidy from another activity to pursue its objectives. The more stringent the competition it faces, the less likely it can remain viable while pursuing its idiosyncratic objectives.

Our model provides a framework that can be extended to further capture the complexity of the journals market and to treat new policy issues that arise as the market matures in the digital age. For example, future work could derive a dynamic extension of the model endogenizing incumbent journals' market power. In such an extension, an incumbent's market power could derive from its monopoly over the digital archive of its past issues or from lags in the adjustment of reputation. New policy issues that might be analyzed using the model include the welfare effects of allowing publishers to negotiate with libraries over large portfolios of journals, raising antitrust concerns relating to both bundling and price discrimination. Second, publishers have begun experimenting with complicated pricing schemes, including ones that offer the author the option to pay extra for open access. The welfare effects of such schemes, as well as the implications for equilibrium under various market-structure assumptions, could be studied using our framework. Third, free access to articles on authors' personal websites and repositories of working papers such as SSRN and arXiv raise questions about readers' and libraries' willingness to pay for access in the near future. Our framework could easily be applied to pricing under such an open-access constraint.

Appendix

Proof of Proposition 1: Let Π_j be the profit of an active journal j in the free-entry equilibrium. We will show $\Pi_j = 0$. Of course it cannot be the case that $\Pi_j < 0$ in equilibrium because j can guarantee itself zero profit by setting sufficiently high prices that it gets no author or reader demand.

We are left to rule out $\Pi_j > 0$ in equilibrium. As a preliminary step, we establish several consequences of $\Pi_j > 0$. First, note that at least one of the prices p_j^A, p_j^R is positive or else $\Pi_j \leq 0$. Furthermore, $n_j^A, n_j^R > 0$ or else $\Pi_j = 0$. Rearranging equation (1),

$$\Pi_j = n_j^A[n_j^R(p_j^A + p_j^R - c) - c^A] - c^R n_j^R. \quad (\text{A1})$$

It is evident that the term in square brackets in (A1) is positive if $\Pi_j > 0$:

$$n_j^R(p_j^A + p_j^R - c) - c^A > 0. \quad (\text{A2})$$

Dividing (A1) through by n_j^R , we see that

$$n_j^A(p_j^A + p_j^R - c) - c^R > 0 \quad (\text{A3})$$

since $c^A/n_j^R \geq 0$.

With these preliminaries in hand, we will show that if $\Pi_j > 0$, an inactive journal can profitably deviate by entering and undercutting journal j 's prices. Let $p_d^A = \max(0, p_j^A - \epsilon, 0)$ and $p_d^R = \max(0, p_j^R - \epsilon)$ be this entering journal's deviating prices. By construction, $p_d^A \in [0, p_j^A]$ and $p_d^R \in [0, p_j^R]$. Take $\epsilon > 0$ to be sufficiently small that either $p_d^A \in (0, p_j^A) \neq \emptyset$ or $p_d^R \in (0, p_j^R) \neq \emptyset$. (Note that either $(0, p_j^A) \neq \emptyset$ or $(0, p_j^R) \neq \emptyset$ because either $p_j^A > 0$ or $p_j^R > 0$.) Let n_d^A and n_d^R be the entering journal's demands. Since $p_d^A \leq p_j^A$ and $p_d^R \leq p_j^R$, $n_d^A \geq n_j^A$ and $n_d^R \geq n_j^R$. We have the inactive journal's profit from this deviation is

$$\Pi_d = \Pi_j + \Delta_d^A[n_d^R(p_d^A + p_d^R - c) - c^A] + \Delta_d^R[n_d^A(p_d^A + p_d^R - c) - c^R] \quad (\text{A4})$$

where $\Delta_d^A = n_d^A - n_j^A$ and $\Delta_d^R = n_d^R - n_j^R$. We will show that if $\Pi_j > 0$, the second and third terms of (A4) are non-negative for sufficiently small $\epsilon > 0$, implying that $\Pi_d > 0$. To sign the second term of (A4), note $\Delta_d^A \geq 0$. Further, $n_j^R(p_d^A + p_d^R - c) - c^A$ can be made arbitrarily close to the left-hand side of (A2) for sufficiently small $\epsilon > 0$, implying $n_j^R(p_d^A + p_d^R - c) - c^A > 0$. But this last inequality implies $p_d^A + p_d^R - c > 0$, in turn implying $n_d^R(p_d^A + p_d^R - c) - c^A \geq$

$n_j^R(p_d^A + p_d^R - c) - c^A > 0$ because $n_d^R \geq n_j^R$. To sign the third term of (A4), note $\Delta_d^R \geq 0$. Further, $n_j^A(p_d^A + p_d^R - c) - c^R$ can be made arbitrarily close to the left-hand side of (A2) for sufficiently small $\epsilon > 0$, implying $n_j^A(p_d^A + p_d^R - c) - c^R > 0$. We have shown thus shown that the entering journal's deviation is profitable, implying $\Pi_j = 0$ for all active journals in equilibrium. \square

The following lemma will be used in the proof of Proposition 2.

Lemma 1. *Suppose $c^R > 0$. In a free-entry equilibrium, one active journal cannot charge both the same author price and reader price as another.*

Proof. Suppose $c^R > 0$. Suppose two journals, labeled 1 and 2, are active (so $n_1^A, n_2^A, n_1^R, n_2^R > 0$), charge equal author prices (so $p_1^A = p_2^A$), and charge equal reader prices (so $p_1^R = p_2^R$). If $\Pi_1 \neq 0$ or $\Pi_2 \neq 0$, then the outcome cannot be an equilibrium. So assume $\Pi_1 = \Pi_2 = 0$.

Before proceeding, we establish a useful fact, (A5). Expressing Π_2 as in equation (A1), noting $\Pi_2 = 0$ and $c^R > 0$, it follows that the factor in square brackets in (A1) is positive for $j = 2$:

$$n_2^R(p_2^A + p_2^R - c) - c^A > 0. \quad (\text{A5})$$

We proceed to show that journal 2 has a profitable deviation, so the posited outcome cannot be an equilibrium. There are two cases to consider. First, suppose $p_1^A = p_2^A > 0$. Journal 2 can increase its profit by deviating to $\tilde{p}_2^A = p_2^A - \epsilon$ for sufficiently small $\epsilon > 0$, holding p_2^R (and thus n_2^R) constant. Intuitively, undercutting in this way is profitable because it captures journal 1's authors (and others besides). Journal 2 earns a positive margin on each author; otherwise it could not have covered fixed reader costs and still break even in the original outcome.

More formally, journal 2's deviation profit is

$$\tilde{\Pi}_2 = \tilde{n}_2^A[n_2^R(\tilde{p}_2^A + p_2^R - c) - c^A] - c^R n_2^R, \quad (\text{A6})$$

where \tilde{n}_2^A is the measure of authors 2 serves as a result of its deviation. Equation (A6) follows from (A1). For sufficiently small $\epsilon > 0$,

$$\tilde{\Pi}_2 \geq (n_1^A + n_2^A)[n_2^R(\tilde{p}_2^A + p_2^R - c) - c^A] - c^R n_2^R \quad (\text{A7})$$

$$> n_2^A[n_2^R(p_2^A + p_2^R - c) - c^A] - c^R n_2^R. \quad (\text{A8})$$

To see (A7), note undercutting induces all authors that originally submitted to journals 1 and 2 to submit to 2, so 2's submissions increase to at least $n_1^A + n_2^A$ (perhaps more if other authors are also attracted by the lower price). Hence $\tilde{n}_2^A \geq n_1^A + n_2^A$. Moreover, the factor in square brackets in (A6) and (A7) is arbitrarily close to the left-hand side of (A5) for sufficiently small $\epsilon > 0$. Thus (A7) holds for sufficiently small $\epsilon > 0$. To see (A8), as argued, the factor in square brackets in (A7) and (A8) are both positive and arbitrarily close to each other for sufficiently small $\epsilon > 0$. But (A8) equals $\Pi_2 = 0$, implying $\tilde{\Pi}_2 > 0$. We have thus demonstrated a profitable deviation if $p_1^A = p_2^A > 0$.

Next, suppose $p_1^A = p_2^A = 0$. Journal 2 can increase its profit by deviating to $\tilde{p}_2^R = p_2^R - \epsilon$ for sufficiently small $\epsilon > 0$, holding $p_2^A = 0$ constant. Intuitively, such a deviation, by attracting a few more readers, causes all the authors to submit to journal 2; this jump in submissions increases 2's profit because it earns a positive margin on each, as seen in the previous paragraph.

More formally, let $\tilde{\Pi}_2$ be 2's deviation profit.

$$\tilde{\Pi}_2 = \tilde{n}_2^A [\tilde{n}_2^R (p_2^A + \tilde{p}_2^R - c) - c^A] - c^R \tilde{n}_2^R, \quad (\text{A9})$$

where \tilde{n}_2^A and \tilde{n}_2^R are 2's author and reader quantities resulting from the deviation. For sufficiently small $\epsilon > 0$,

$$\tilde{\Pi}_2 \geq \tilde{n}_2^A [\tilde{n}_2^R (p_2^A + \tilde{p}_2^R - c) - c^A] - c^R \tilde{n}_2^R \quad (\text{A10})$$

$$> n_2^A [n_2^R (p_2^A + p_2^R - c) - c^A] - c^R n_2^R. \quad (\text{A11})$$

Condition (A11) holds because $\tilde{n}_2^A \geq n_1^A + n_2^A$ and because the factor in square brackets can be made arbitrarily close to the left-hand side of (A5), which is positive by (A5). Condition (A11) holds for sufficiently small $\epsilon > 0$ because (a) the term in square brackets in (A11) can be made arbitrarily close to that in (A11), which is positive by (A5); (b) the term $c^R \tilde{n}_2^R$ can be made arbitrarily close to $c^R n_2^R$ in (A11), and (c) the leading factor in (A11), $n_1^A + n_2^A$, is strictly greater than the leading factor in (A11), n_2^A . This is true since $n_1^A > 0$ because journal 1 is active in the original outcome. Hence, we have shown that 2 has a profitable deviation in all cases, so the original outcome could not have been an equilibrium. \square

Proof of Proposition 2: Suppose $c^R > 0$ throughout the proof. In step 1 of the proof, we use revealed-preference arguments to show that the authors divide themselves into the partitions as stated. Two conditions are equivalent to the stated

author partition: (a) there are no unserved authors above the lowest type served, B_n^A ; (b) each journal j serves a connected interval, i.e., no author in (B_j^A, B_{j-1}^A) is served by a journal other than j .

To prove (a) holds in free-entry equilibrium, suppose author i with value b_i^A is unserved and author k with valuation $b_k^A < b_i^A$ is served by some journal j . This cannot be an equilibrium. Author i could strictly benefit by deviating and submitting to journal j , earning surplus $n_j^R(b_i^A - p_j^A) > n_j^R(b_k^A - p_j^A) \geq 0$. The second inequality holds because author k weakly prefers to be served by journal j than not to be served.

To prove (b) holds in free-entry equilibrium, suppose authors i and k are served by one active journal (without loss of generality labeled 1) and author ℓ is served by another (labeled 2), and suppose $b_k^A < b_\ell^A < b_i^A$. A series of calculations will show that these revealed author preferences are consistent only if journals offer equal author and reader prices.

The facts that author i weakly prefers journal 1 and ℓ weakly prefers journal 2 imply, respectively,

$$n_1^R(b_k^A - p_1^A) \geq n_2^R(b_k^A - p_2^A) \quad (\text{A12})$$

$$n_2^R(b_\ell^A - p_2^A) \geq n_1^R(b_\ell^A - p_1^A). \quad (\text{A13})$$

But then

$$(n_2^R - n_1^R)b_k^A \leq n_2^R p_2^A - n_1^R p_1^A \quad (\text{A14})$$

$$\leq (n_2^R - n_1^R)b_\ell^A \quad (\text{A15})$$

$$\leq (n_2^R - n_1^R)b_i^A. \quad (\text{A16})$$

Condition (A14) follows from (A12) and (A15) from (A13). To see (A16), note (A14) and (A15) together with $b_k^A < b_\ell^A$ imply $n_2^R - n_1^R \geq 0$. But then (A15) together with $b_\ell^A < b_i^A$ imply (A16).

Conditions (A14) through (A16) imply

$$n_2^R(b_i^A - p_2^A) \geq n_1^R(b_i^A - p_1^A). \quad (\text{A17})$$

Condition (A17) is consistent with author i 's weakly preferring journal 1 over 2 only if (A17) holds as an equality. But then (A15) and (A16) must also hold as equalities, implying $n_1^R = n_2^R$ and $n_1^R p_1^A = n_2^R p_2^A$, in turn implying $p_1^A = p_2^A$ and $p_1^R = p_2^R$. By Lemma 1, the journals' charging equal prices is inconsistent with free-entry equilibrium.

This completes step 1 of the proof that authors divide themselves into the stated partitions. The author partition establishes the labeling of journals $j = 1, \dots, J$. In step 2, we show that readers divide themselves into partitions consistent with the established labeling of journals. Two conditions are equivalent to the stated partition: (a) journal j serves all readers above the lowest type it serves, B_j^R ; (b) journal $j - 1$ serves strictly more readers than journal j .

To prove (a) holds in free-entry equilibrium requires similar revealed-preference arguments to those used to prove part (a) of the previous step. We omit the arguments for brevity.

To prove (b) holds in free-entry equilibrium, note that active journals $j - 1$ and j cannot serve the exact same number of readers, for then $p_{j-1}^R = p_j^R$. Furthermore, $p_{j-1}^A = p_j^A$ or else the high-price one would have no authors and would be inactive. But if $p_{j-1}^A = p_j^A$, $p_{j-1}^R = p_j^R$, and both journals are active, Lemma 1 implies the outcome cannot be a free-entry equilibrium.

So suppose j serves more readers than $j - 1$. A revealed-preference argument can be used to show that journal $j - 1$'s authors would prefer to submit to j than to $j - 1$ given that authors with lower types prefer to submit to j . It would follow that $j - 1$ would be inactive. So j cannot serve more readers than $j - 1$. This establishes that (b) holds in free-entry equilibrium.

The final step of the proof of case (i) is to verify the stated ordering of prices. It is clear that $p_{j-1}^R < p_j^R$ for all $j = 1, \dots, J$, because $B_{j-1}^R < B_j^R$, i.e., journal $j - 1$ serves all of journal j 's readers and more. In order for some authors to prefer to submit to j , required for j to be active, $p_j^A < p_{j-1}^A$. Thus author and reader prices are ordered as stated. \square

Proof of Proposition 3: Suppose $c^R = 0$ throughout the proof. Consider an outcome in which a positive measure of authors M are served by a journal j that does not maximize the authors' surpluses

$$n_j^R(b_i^A - p_j^A) = [1 - F^R(p_j^R)](b_i^A - p_j^A) \quad (\text{A18})$$

subject to the non-negative price constraints $p_j^A, p_j^R \geq 0$ and the break-even constraint

$$n_j^A[n_j^R(p_j^A + p_j^R - c) - c^A] - c^R n_j^R \geq 0, \quad (\text{A19})$$

where (A19) is equivalent to

$$[1 - F^R(p_j^R)](p_j^A + p_j^R - c) - c^A \geq 0. \quad (\text{A20})$$

Then there exists $\tilde{p}_j^A, \tilde{p}_j^R > 0$ such that

$$[1 - F^R(\tilde{p}_j^R)](b_i^A - \tilde{p}_j^A) > [1 - F^R(p_j^R)](b_i^A - p_j^A) \quad (\text{A21})$$

and

$$[1 - F^R(\tilde{p}_j^R)](\tilde{p}_j^A + \tilde{p}_j^R - c) - c^A > 0. \quad (\text{A22})$$

By continuity, for small enough $\epsilon > 0$, conditions (A21) and (A22) also hold for all author types in an ϵ neighborhood $N_\epsilon(b_i^A) = (b_i^A - \epsilon, b_i^A + \epsilon)$ around b_i^A within measure M . A journal can enter the market, charge prices \tilde{p}_j^A and \tilde{p}_j^R , and make positive profit equal to the positive marginal profit per author in condition (A22) times the measure of authors these prices attract, at least the measure of $N_\epsilon(b_i^A)$.

To show that expression (9) is equivalent to maximizing author type b_i^A 's gross surplus subject to constraint (A20) and non-negative price constraints, note that (A20) binds at an optimum since lowering either price increases the author's surplus, but (A20) is violated if prices are set to zero. Treating (A20) as an equality and solving for p_j^A ,

$$p_j^A = \frac{c^A}{1 - F^R(p_j^R)} + c - p_j^R. \quad (\text{A23})$$

Substituting equation (A23) into (A18) gives the objective function in (9). Constraining $p_j^A \geq 0$ in (A23) gives the constraint on p_j^R in (9).

The proof is completed by determining which author types are served. A type b_i^A is served if and only if for the p_j^A for which (A18) is non-negative, (A20) is satisfied. For (A18) to be non-negative, $p_j^A \leq b_i^A$. But (A20) is satisfied for $p_j^A = b_i^A$ if and only if (11) holds. \square

Proof of Proposition 5: The proof for set (i) follows from Proposition 4.

To analyze set (ii), suppose $c^R > 0$. We will show that under (12) an open-access journal can enter, capture type \underline{b}^A and all higher-type authors, and earn positive profit. As a first step, we will show that if (12) holds, an open-access journal can profitably enter if no journal is presently serving the market. The entering journal can charge $p^A = \underline{b}^A$ and $p^R = 0$, serve measure 1 of authors and all readers, and earn $\underline{b}^A - c^A - c^R - c$, which is positive by (12).

It remains to show that if some authors are presently served by journals that are all closed-access, an open-access journal can profitably enter by capturing the authors from the active journals. The maximum utility that can feasibly be

provided to a type- \underline{b}^A author solves a problem we will label MAX1:

$$\max_{p_j^A, p_j^R \geq 0} n_j^R(\underline{b}^A - p_j^A) \quad \text{subject to} \quad (A24)$$

$$n_j^A n_j^R(p_j^A + p_j^R - c) - c^A n_j^A - c^R n_j^R \geq 0. \quad (A25)$$

A weakly higher maximum than MAX1, labeled MAX2, can be obtained by substituting a weaker condition than (A25). As argued in the proof of Lemma 1, $c^R > 0$ implies that the margin on authors must be positive for (A25) to hold. Substituting $n_j^A = 1$ (the highest possible number of authors) into (A25) and rearranging,

$$p_j^A \geq \frac{c^A}{n_j^R} + c^R + c - p_j^R. \quad (A26)$$

We complete the derivation of MAX2 by recognizing that (A26) will hold with equality at an optimum, using (A26) to substitute out for p_j^A in (A24), and substituting $n_j^R = 1 - F^R(p_j^R)$. We then have the following representation of MAX2:

$$\max_{p_j^R} \{ [1 - F^R(p_j^R)](\underline{b}^A - c^R - c + p_j^R) \} - c^A. \quad (A27)$$

The Lagrangian associated with (A27) is

$$[1 - F^R(p_j^R)](\underline{b}^A - c^R - c + p_j^R) + \lambda p_j^R, \quad (A28)$$

where λ is the Lagrange multiplier on the constraint $p_j^R \geq 0$. Taking the first-order condition with respect to p_j^R and rearranging,

$$\lambda = f^R(p_j^R)(\underline{b}^A - c^R - c + p_j^R) - [1 - F^R(p_j^R)]. \quad (A29)$$

It can be seen that $\lambda > 0$, in turn implying $p_j^R = 0$ at an optimum, if

$$\underline{b}^A > c^R + c + \frac{1 - F^R(p_j^R)}{f^R(p_j^R)} - p_j^R, \quad (A30)$$

which holds for all $p_j^R \in [0, \bar{b}^R]$ if (12) holds.

We have shown that the solution to MAX2 involves an open-access journal. Assuming the journal serves measure 1 of authors, it generates the same value in MAX1 as in MAX2. But since MAX2 is weakly higher than MAX1, the solution

to MAX1 must involve open access as well. It remains to be argued that the entrant indeed serves measure 1 of authors. A revealed-preference argument can be used to show that if the entrant succeeds in capturing author type \bar{b}^A with an open-access pricing policy, it will capture all higher types as well.

Hence we have shown that an open-access journal can capture measure 1 of authors and earn non-negative profit. The fact that the Lagrange multiplier λ was strictly positive indicates that the \bar{b}^A type gained strictly higher utility from the open-access journal than from any closed-access journal, and so could still be induced to switch to the open-access entrant even if the entrant charged strictly a higher author price. But this strictly higher author price would allow the entrant to earn strictly positive profit, and so we have demonstrated a strictly profitable entry opportunity. This implies that the free-entry equilibrium must involve an open-access journal.

To analyze set (iii), condition (13) implies

$$\bar{b}^A > c + \max_{p_j^R \in [0, c+c^A/[1-F^R(p_j^R)]]} \left\{ \frac{[1 - F^R(p_j^R)]p_j^R}{F^R(p_j^R)} \right\} \quad (\text{A31})$$

because the right-hand side of (A31) involves a smaller range over which the maximization is performed than the right-hand side of (13). After rearranging, (A31) implies

$$\bar{b}^R - c > [1 - F^R(p_j^R)](\bar{b}^R + p_j^R - c) \quad (\text{A32})$$

for all

$$p_j^R \in \left[0, c + \frac{c^A}{1 - F^R(p_j^R)} \right]. \quad (\text{A33})$$

Substituting $b_i^A = \bar{b}^A$ and $p_j^R = 0$ into the value function in (9) gives the value $\bar{b}^A - c$. This value is higher than if any other value of p_j^R satisfying (A33) is substituted, implying $p^R(\bar{b}^A) = 0$. Since the inequality in (A32) is strict, $p^R(b_i^A) = 0$ for all b_i^A in a neighborhood below \bar{b}^A as well. By Proposition 3, this neighborhood of authors is served by an open-access journal or journals. \square

Proof of Proposition 7: Arguments along the lines of the proof of Proposition 3 can be used to show that the free-entry equilibrium maximizes $b_i^A q_i - n_j^R p_j^A$, the net surplus of author type (b_i^A, q_i) (now a vector type rather than a scalar) subject to non-negative price constraints $p_j^A, p_j^R \geq 0$ and a break-even constraint for the journal $n_j^A [n_j^R (p_j^A + p_j^R - c) - c^A] \geq 0$. Noting that $b_i^A q_i$ is an inessential constant

in the objective function and making the change of variables $\tilde{p}_j^A = n_j^R p_j^A$, the maximization problem can be rewritten $\min \tilde{p}_j^A$ subject to $\tilde{p}_j^A \geq 0$, $p_j^R \geq 0$, and

$$\tilde{p}_j^A \geq c^A - [1 - F^R(p_j^R/q_i)](p_j^R - c). \quad (\text{A34})$$

The solution depends on which constraint, $\tilde{p}_j^A \geq 0$ or (A34), binds first, which in turn depends on the sign of

$$\min_{p_j^R \geq 0} \{c^A - [1 - F^R(p_j^R/q_i)](p_j^R - c)\}, \quad (\text{A35})$$

where (A35) is the minimized value of the right-hand side of constraint (A34). If (15) holds, then (A35) is non-positive, and constraint $\tilde{p}_j^A \geq 0$ binds before (A34). Free-entry equilibrium thus involves $p^A(q_i) = 0$ and any p_j^R that satisfies (A34) with 0 substituted in the left-hand side. If (15) does not hold, then $p^A(q_i)$ can be found by treating (A34) as an equality with $p^R(q_i)$ set to minimize the right-hand side. Dividing $\tilde{p}^A(q_i)$ through by $1 - F^R(p^R(q_i)/q_i)$ gives the value of $p^A(q_i)$ in the statement of the proposition. \square

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